A Young Stellar Cluster Surrounding the Peculiar Eruptive Variable V838 Monocerotis[1]

Melike Afşar[2] and Howard E. Bond

Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218; melike.afsar@ege.edu.tr, bond@stsci.edu

ABSTRACT

V838 Monocerotis is an unusual variable star that underwent a sudden outburst in 2002. Unlike a classical nova, which quickly evolves to high temperatures, V838 Mon remained an extremely cool, luminous supergiant throughout its eruption. It continues to illuminate a spectacular series of light echoes, as the outburst light is scattered from nearby circumstellar dust. V838 Mon has an unresolved B3 V companion star.

During a program of spectroscopic monitoring of V838 Mon, we serendipitously discovered that a neighboring 16th-mag star is also of type B. We then carried out a spectroscopic survey of other stars in the vicinity, revealing two more B-type stars, all within 45″ of V838 Mon. We have determined the distance to this sparse, young cluster, based on spectral classification and photometric main-sequence fitting of the three B stars. The cluster distance is found to be 6.2 ± 1.2 kpc, in excellent agreement with the geometric distance to V838 Mon of 5.9 kpc obtained from *Hubble Space Telescope* polarimetry of the light echoes. An upper limit to the age of the cluster is about 25 Myr, and its reddening is $E(B-V) = 0.85$.

The absolute luminosity of V838 Mon during its outburst, based on our distance measurement, was very similar to that of M31 RV, an object in the bulge of M31 that was also a cool supergiant throughout its eruption in 1988. However, there is no young population at the site of M31 RV.

Using our distance determination, we show that the B3 V companion of V838 Mon is sufficient to account for the entire luminosity of the variable star measured on sky-survey photographs before its outburst. The B3 star is currently, however, about 1 mag fainter than before the eruption, suggesting that it is now suffering extinction due to dust ejected from V838 Mon. These results indicate that, whatever the nature of the progenitor object, it was not of high luminosity. Nor does it appear possible to form a nova-like cataclysmic binary system within the young age of the V838 Mon cluster. These considerations appear to leave stellar-collision or -merger scenarios as one of the remaining viable explanations for the outbursts of V838 Mon and M31 RV.

---

[1]Based on observations made with the Small- and Medium-Aperture Research Telescope System (SMARTS).

[2]Current address: Department of Astronomy and Space Sciences, Ege University, 35100 Bornova, İzmir, Turkey

Subject headings: binaries: general—open clusters and associations: individual (V838 Mon)—novae, cataclysmic variables—stars: individual (M31 RV, V838 Mon, V4332 Sgr)—stars: variables: other

1. Introduction

The outburst of the previously unknown variable star V838 Monocerotis was discovered in 2002 January by Brown (2002). By early February V838 Mon reached 6th magnitude, but by 2002 May it had returned to quiescence at optical wavelengths. Shortly after maximum light, an expanding light echo was discovered by Henden, Munari, & Schwartz (2002). These light echoes have evolved to become the most spectacular display of the phenomenon in astronomical history. They have been the subject of extensive imaging by ground-based observers (e.g., Crause et al. 2005 and references therein) and with the *Hubble Space Telescope* (*HST*) (Bond et al. 2003, 2006).

The eruption of V838 Mon was of a very unusual type. In a classical-nova outburst, the ejecta expand rapidly, become optically thin, and expose an extremely hot source. By contrast, V838 Mon remained extremely cool throughout its outburst, becoming one of the coolest known stars—in fact it has been called the first L-type supergiant (Evans et al. 2003). In 2005 it developed rapidly strengthening SiO maser emission (Claussen et al. 2005). A variety of explanations for the outburst have been proposed, many of them mutually exclusive (see the recent summary in Tylenda & Soker 2006, and the forthcoming proceedings of an international conference on V838 Mon—Corradi & Munari 2006). These explanations involve either thermonuclear processes (an unusual nova-like outburst on a white dwarf, a thermonuclear event in a massive star, or a helium shell flash in a post-AGB star), or the release of gravitational energy (through stellar or planetary mergers or collisions).

A possible new constraint on the nature of V838 Mon came from the spectroscopic discovery of a B3 V companion to the variable star (Munari & Desidera 2002; Wagner & Starrfield 2002). The companion is unresolved even in *HST* images.[1] However, it is not close enough to the variable to have been engulfed when V838 Mon expanded to a radius of several AU.

Two other eruptive objects have attracted attention as possible analogs of V838 Mon. One of them is the "M31 red variable," or "M31 RV," which underwent an outburst in mid-1988 that was remarkably similar to that of V838 Mon (Bond & Siegel 2006 and references therein), although not as well observed. M31 RV occurred in the nuclear bulge of the Andromeda Galaxy, and is thus at a known distance. The other is V4332 Sgr, a Galactic object that had a nova-like outburst in 1994

[1] In an unpublished analysis, we have examined the *HST* images of V838 Mon obtained in late 2002 (which have been discussed by Bond et al. 2003). At that time the B light was dominated by the B3 V star, while the cool outbursting star dominated at V and I. We detect no centroid shift of greater than $0\farcs1$ between the blue and red images.

during which it likewise remained very cool (Martini et al. 1999; Tylenda et al. 2005 and references therein).

In this paper, we present our serendipitous discovery that V838 Mon is a member of a small, young open cluster. We will use spectral classification and photometry of the cluster members to determine a distance, which we will compare with the direct geometric distance to V838 Mon derived from *HST* polarimetry of the light echoes. We will also derive a limit to the cluster's age, and will compare the stellar populations surrounding V838 Mon and M31 RV. We will close with a brief discussion of the V838 Mon progenitor object, its B3 companion, and some new constraints on the outburst mechanism that result from our observations.

2. Observations and Data Reduction

2.1. Spectroscopy

We have been monitoring the spectroscopic development of V838 Mon since early 2003, using the SMARTS 1.5-m telescope located at Cerro Tololo Interamerican Observatory (CTIO) and the Boller & Chivens CCD spectrograph. Most of our observations have been obtained with a 600 groove mm^{-1} grating used in first order (grating designation "26/I"), yielding a FWHM resolution of 4.3 Å and a wavelength coverage of 3530–5300 Å. The CCD images are bias-subtracted and flat-fielded using standard IRAF[2] routines, and the spectra are then extracted from the images using the *apall* task. Wavelength calibration is accomplished using He-Ar comparison-lamp exposures taken before and after each stellar exposure.

Our data are long-slit spectra, in which the slit length projected onto the sky is about $6'$, in an east-west direction. It is not unusual for neighboring field stars to fall onto the slit, but we were surprised when a 16th-mag star lying on the slit almost directly east of V838 Mon proved, entirely serendipitously, to have a B-type spectrum. Although V838 Mon lies at a low galactic latitude ($\ell = 217^\circ\!.8$, $b = +1^\circ\!.0$), a B-type star as faint as 16th mag would lie at the outskirts of the Galactic disk. This makes its existence very unusual, especially when lying within a few arcseconds of a star that is itself extraordinary. Adding this to the fact that V838 Mon has an unresolved B companion made it appear very likely that the serendipitous star is at the same distance. This in turn raised the possibility that there could be further faint early-type objects in the field surrounding V838 Mon.

To investigate this possibility, we have used the SMARTS 1.5-m telescope to obtain spectra of several more stars in the immediate vicinity of V838 Mon. For these exploratory observations we used a 150 groove mm^{-1} grating (designation "13/I"), giving a resolution of 17.2 Å and coverage 3150–9375 Å. Most of the neighboring stars have proven to be unrelated foreground stars, but

[2]IRAF is distributed by the National Optical Astronomy Observatory, which is operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

our observations to date have disclosed two further 14th-15th mag B-type stars near V838 Mon. All three of these early-type stars lie within $45''$ of the variable, or within a projected separation of only 1.3 pc if the distance is $\sim$6 kpc (see below). Thus there is little doubt that V838 Mon is accompanied by a previously unrecognized sparse, young cluster.

Table 1 lists some properties of the new B-type stars near V838 Mon. The coordinates are taken from the NOMAD-1.0 astrometric catalog (Zacharias et al. 2004). Other information in Table 1 is explained below.

Figure 1 presents a finding chart that identifies the new B stars, using an arbitrary numbering scheme. Star 7 is the serendipitous B star discovered first, lying nearly directly east of V838 Mon; the other two B stars are numbers 8 and 9. All of the other numbered stars marked in Figure 1 are unrelated foreground stars, based on our 1.5-m spectroscopic observations. (In addition, the bright star $\sim 20''$ to the northeast of star 4 has colors showing it to belong to the foreground, based on our photometry described below.) Figure 1 illustrates that the cluster is not obvious in a direct image, and as we will see below the reddened B-type members and foreground F-G stars have similar colors; hence spectroscopic observations are the only practical means for identifying cluster members in this crowded, low-latitude field.

As this paper was being prepared, we became aware that Wisniewski, Bjorkman, & Magalhães (2003; hereafter WBM2003) had already pointed out that our three stars are likely to lie at a similar distance to V838 Mon itself, based on the similar polarimetric properties of all four stars. Wisniewski et al. used a different numbering scheme for these stars, and we give cross references to their star numbers in the second column of Table 1.

Photometry for the field surrounding V838 Mon has been published by Munari et al. (2005; hereafter M05), and cross references to their numbering system are given in the third column of Table 1.

2.2. Spectral Classification

Following the serendipitous discovery of the first field B-type star, and our subsequent discoveries of two more B stars with the low-resolution 13/I grating setup, we obtained moderate-resolution of the latter two with the SMARTS 1.5-m spectrograph and the moderate-resolution 26/I grating. In Figure 1 we show these spectra, along with spectra of several classification standards taken with the same setup. The spectra of stars 8 and 9 are exposures of 3×800 s and 3×600 s, respectively, obtained in 2004 December, while the spectrum of star 7 is derived from 26/I spectra of V838 Mon taken on 20 nights in 2003-2004 in which star 7 also lies on the slit. The exposures on V838 Mon were typically 3×900 s on each night, but since star 7 is not precisely east of the variable not all of its light falls within the slit. Also included in Figure 1 is a spectrum of V838 Mon itself based on observations on five nights between 2003 February and May, a time when the variable had declined considerably from its 2002 outburst, but was still contributing some light even in this blue spectral range (note the TiO bands longward of Hβ, for example).

We classified the three B stars based both upon a visual comparison with the standard stars shown in Figure 2, and upon equivalent-width measurements of the He I and Balmer lines. The results are given in Table 1 and are believed to be accurate to better than one spectral subtype. We were not able to classify the unresolved B-type companion of V838 Mon itself with these methods because of the contamination from the cool component. However, from a comparison of the equivalent widths of the bluest Balmer lines (H8, H9, and H10) in V838 Mon (where the contamination is lowest) and in the standard stars, we find a type of B3 V. This agrees well with the other authors cited in §1.

2.3. Photometry

We have also been monitoring the field of V838 Mon regularly since early 2003 with the SMARTS 1.3-m telescope and the ANDICAM optical/near-infrared direct camera (DePoy et al. 2003). In order to derive calibrated photometry of the stars surrounding V838 Mon, we selected frames obtained on five photometric nights in 2003-2004 on which the Ru 149 standard field from Landolt (1992) had been observed at a similar airmass (so as to essentially remove the dependence of the calibration upon variations in atmospheric extinction coefficients).

We used standard IRAF routines for bias subtraction and flat-fielding of the 2003 CCD frames (starting in 2003 August, however, ANDICAM data have been reduced through a pipeline at Yale University before distribution to observers). We then used the IRAF implementation of DAOPHOT (Stetson 1987) for star finding and to obtain point-spread-function (PSF) instrumental magnitudes for the stars. These magnitudes were then transformed to the Johnson BV system using the Landolt standards. The results are given in Table 2. The internal errors in V and $B-V$ are about ±0.004 and ±0.005 mag, respectively, for the two brighter stars, and about ±0.005 and ±0.007 mag, respectively, for star 7. However, since typically only one Landolt field was observed per night, the external errors are probably closer to ±0.01-0.02 mag.

When we compared our photometry with that published by M05 for the same three stars, we found very large discrepancies (up to $\sim$0.7 mag in V), and we also noted that unusually large errors are listed by M05 for two of the three stars. Variability does not account for the large discrepancies, since we find constancy for all three stars, leaving us with no clear explanation.[3] We have performed several checks on our photometric measurements, and are confident that our results are reliable.

---

[3]Bacher et al. (2005, caption to their Fig. 2) note that the M05 photometry was obtained while V838 Mon was very bright, thus providing a possible explanation for the poor photometry for stars very close to the variable. As this paper was being completed, we received a private communication from A. Henden indicating that his recent update of the M05 photometry shows much better agreement with our results.

3. Distance and Other Properties of the Cluster

3.1. Spectroscopic Parallax

We can now calculate distances to each of the three B stars, and thus determine a distance to the cluster. Details of the calculations are given in Table 2. The first four columns repeat the star designations, spectral types, and photometry from Table 1. The fifth column gives the intrinsic color corresponding to each spectral type, $(B-V)_0$, taken from the tabulation of Schmidt-Kaler (1982). The sixth column gives the estimated color excess, $E(B-V) = (B-V) - (B-V)_0$. The color excesses agree well among the three stars, with a mean of $E(B-V) = 0.84$ and a scatter of about ± 0.02 mag. This determination agrees well with those of other authors. For example M05 found $E(B-V) = 0.87 \pm 0.01$ using several different methods. Tylenda (2005) discusses recent reddening determinations by several authors, and adopts $E(B-V) \simeq 0.9$. It should be noted, however, that these authors have given high weight to methods based on the unresolved B3 companion of V838 Mon, which (as discussed below) may suffer some local extinction in addition to foreground interstellar extinction.

The next column in Table 2 gives the magnitude of each star corrected for extinction, V_0, calculated assuming $A_V = 3.1E(B-V)$. Column 8 gives the absolute magnitude corresponding to each spectral type, M_V, again taken from Schmidt-Kaler (1982). The final column gives the distance moduli, $(m-M)_0$, whose mean is 14.0, or a distance of 6.3 kpc.

The cluster distance modulus has an internal error of about ± 0.2 mag, based on the scatter among the three stars. However, systematic errors are undoubtedly larger. This is indicated by the scatter among different calibrations of the relation between spectral types and absolute magnitudes (e.g., Lesh 1968; Schmidt-Kaler 1982; Cramer 1997), which amounts typically to about ± 0.4 mag. At a distance of 6.3 kpc, this corresponds to an error of ± 1.2 kpc.

3.2. Main-sequence Fitting

We can also estimate the distance to our cluster through photometric main-sequence fitting. In the absence of any spectroscopic information, this method would suffer from the well-known near-degeneracy between extinction and distance for early-type stars; this is due to fact that the main sequence lies along a steep, nearly straight line in the $V, (B-V)$ diagram. However, with the additional constraints from the spectral types, main-sequence fitting become possible.

To define the main sequence, we chose the lightly reddened open cluster NGC 2362, which, at an age of $\sim$5 Myr, has been described as a template for early stellar evolution (Moitinho et al. 2001; hereafter MAHL01). This cluster's unevolved main sequence extends to type B1 V (Johnson & Morgan 1953). We took B, V photometry for NGC 2362 from Johnson & Morgan and from Perry (1973), and adopted $E(B-V) = 0.10$ and $d = 1.48$ kpc from MAHL01. We then corrected the photometry to the spectroscopic reddening and distance for the V838 Mon cluster found above. The match with the three V838 Mon B stars was very good, so we applied just one iteration of adjusting first the reddening of the B stars and then the distance, so as to improve the fit. This resulted in a V838 Mon cluster reddening of $E(B-V) = 0.85$ and distance modulus $(m-M)_0 = 13.97$ ($d = 6.2$ kpc). The external errors here are similar to those for the spectroscopic parallax, since MAHL01 based the distance to NGC 2362 on the Schmidt-Kaler (1982) zero-age main sequence.

In Figure 3 we plot the $V, (B-V)$ values for the three B stars as large filled blue circles. The small open red circles are the Johnson-Morgan and Perry photometry of NGC 2362, adjusted to the V838 Mon reddening and distance found in the previous paragraph. The fit is excellent, and strongly supports the conclusion that our three B stars do form a physical cluster.

A direct geometrical distance determination for V838 Mon has been carried out by Sparks et al. (2006), based on polarimetric imaging of the light echo obtained with *HST*. This result, 5.9 kpc, is in excellent agreement with our determination of 6.2 kpc based on the associated B-type stars.

Also plotted in Figure 3, as small filled black circles, is our photometry for all stars within a radius of $90''$ of V838 Mon. For most of these stars we do not know whether they are cluster members or not, but we do have SMARTS 1.5-m spectra for six of them that establish them as belonging to the foreground; these non-members are marked with black stars in Figure 3, and they are numbered in the finding chart in Figure 1.

As Figure 3 shows, the foreground F- and G-type stars have similar colors to the reddened B-type cluster members. This demonstrates that spectroscopic observations are essential to the identification of cluster members. It would be very interesting to have spectra of the other stars in the vicinity of V838 Mon, especially below $V \simeq 17.5$, where the slope of the main sequence changes; any of these candidates that proved to be cluster members would provide tighter constraints on the cluster reddening and distance.

We can compare the luminosity of V838 Mon with that of the apparently similar object M31 RV (see §1). At maximum light (2002 February 6) V838 Mon had $B = 7.9$ (M05, their Figure 1). For the reddening and distance derived here, this corresponds to an absolute blue magnitude at maximum of $M_B = -9.6$. The brightest B magnitude measured for M31 RV during its 1988 outburst was 17.3 (Bryan & Royer 1992; Boschi & Munari 2004). The latter authors, adopting $E(B-V) = 0.12$ and $(m-M)_0 = 24.48$ for M31, found an absolute magnitude of $M_B = -7.7$. However, the light curve of M31 RV was very poorly sampled around its maximum. It is more meaningful to compare the luminosities of the two objects at the same well-covered portions of both light curves. Referring to Figure 2 of Boschi & Munari (2004), and using their light curves in Kron-Cousins R, we can compare the luminosities at a point just before the rapid fading in the R band. For M31 RV, this brightness is $R \simeq 15$, and for V838 Mon it is $R \simeq 6.2$. Correcting for reddening and distance, the corresponding absolute magnitudes are $M_R \simeq -9.8$ and -9.7, respectively. Thus, at least at this stage in their outbursts, the absolute luminosities were nearly identical.[4]

---

[4]However, the referee has pointed out that there are some spectroscopic dissimilarities between V838 Mon and

3.3. Diffuse Interstellar Bands

As shown in Figure 2, the spectra of our three B-type stars exhibit conspicuous diffuse interstellar band (DIB) features centered near 4428 Å. We measure the average equivalent width of the 4428 Å DIB in these three stars to be about 3.1 Å. Snow, Zukowski, & Massey (2002, their Fig. 6) show that there is a correlation between the DIB equivalent width and the amount of interstellar extinction in a large sample of Galactic stars, but with considerable scatter. At a reddening of $E(B-V) = 0.85$, our mean equivalent width is at the upper envelope of the values plotted by Snow et al.

These strong DIBs will provide a useful spectroscopic discriminant in future attempts to identify faint members of the V838 Mon cluster.

3.4. Cluster Age and Stellar Masses

Since the three B stars all appear to lie on the zero-age main sequence, we can only set an upper limit to the age of the V838 Mon cluster. By reference to the isochrones and evolutionary tracks[5] of Pientrinfini et al. (2006), we find that this upper limit is about 25 Myr. According to these isochrones, the masses of stars 7, 8, and 9 are about 4.7, 6.4, and 6.7 $M_\odot$, respectively.

4. Discussion

4.1. The Stellar Populations of V838 Mon and M31 RV

V838 Mon is accompanied by a previously reported, unresolved B3 V companion. In this paper we have shown that V838 Mon also belongs to a sparse cluster, containing at least three other members, lying at the outer edge of the Milky Way disk. The main sequence of this cluster extends up to spectral type B3 V, implying an age of less than 25 Myr.

We could thus be tempted to speculate that the outburst of V838 Mon in 2002 represents an evolutionary event that occurs in stars of masses $\gtrsim$7–8 $M_\odot$. We could even speculate that such events occur in stars whose masses lie near the dividing line between those that explode as Type II supernovae and those that become white dwarfs more quiescently.

Unfortunately, such a speculation appears to be dashed by the recent study of M31 RV by Bond & Siegel (2006). They used archival *HST* images that serendipitously included the outburst

---

M31 RV. For example, a comparison of the spectrum of V838 Mon of Evans et al. (2003, their Fig. 2) and of M31 RV by Rich et al. (1989, their Fig. 4) shows that the former had much stronger TiO bands.

[5]Available at http://www.te.astro.it/BASTI/index.php

site of M31 RV, and showed that the population surrounding the object contains exclusively old, low-mass stars belonging to the nuclear bulge of M31. There is no young population at all at this site, let alone bright B stars younger than 25 Myr.

Thus, if the outbursts of both V838 Mon and M31 RV arose from a common mechanism, it is a mechanism that can occur among both very young and very old stars.

4.2. The Underluminous B3 V Companion of V838 Mon

Several authors (e.g., Tylenda, Soker, & Szczerba 2005 and references therein) have attempted to determine the brightness of V838 Mon before its 2002 outburst. The available material for such a determination at optical wavelengths comes from the various photographic sky surveys, and from sky-patrol photographic plates. Archival patrol plates show that the star did not vary over the interval from 1928 to 1994 (Goranskij et al. 2004); however, Kimeswenger & Eyres (2006) have provided evidence suggesting that there was some fading of V838 Mon in the late 1990's, shortly before the onset of the outburst.

In an analysis of high-resolution digitizations of a SERC survey plate obtained in 1983 with a J emulsion, Kimeswenger & Eyres (2006) report that V838 Mon had a B_J magnitude of 15.49 ± 0.09. Adopting a transformation equation of $B = B_J + 0.28(B - V)$ (Bacher, Kimeswenger, & Teutsch 2005 and references therein), and assuming that V838 Mon at that time had the same $B - V$ color as our star 9, we find that its B magnitude in 1983 was 15.66. (Goranskij et al. 2004, in an independent analysis based on the lower-resolution scans of the plate material available in the Digitized Sky Survey, find a slightly fainter pre-outburst value of $B = 15.81 \pm 0.06$.)

The companion of V838 Mon, if it is a normal B3 V star, would be expected to have a luminosity similar to that of our star 9, also classified B3 V. According to our photometry (Table 1), star 9 has a B magnitude of 15.41. This is in fact slightly brighter than the actual pre-outburst B magnitude of V838 Mon found above, suggesting that *the progenitor of the outbursting object contributed a negligible fraction of the pre-eruption light.* (Even if the unresolved companion were in fact more similar to our slightly later star 8, which we classified B4 V and has $B = 15.63$, it still would have contributed *all* of the pre-outburst light.)

It is well established that when V838 Mon subsided back to quiescence (at optical wavelengths) in mid-2002, it was significantly fainter than before the outburst (see, for example, the light curves in Figure 1 of M05, and those given by Goranskij et al. 2004). This faintness has continued to the present time; for example, our own recent SMARTS 1.3-m observation, obtained on 2006 February 19, shows V838 Mon at $B = 16.61$. (Actually, this is an upper limit to the current brightness of the B3 star, since there is some contribution of light from the outbursting companion; however, our spectrum of V838 Mon in Figure 2 indicates that the contribution in the B band is relatively small.)

In order to explain this fading by ∼1 mag, several authors have argued that the progenitor of the outbursting object contributed significant optical light to the pre-outburst magnitude, and that this extra light is now absent or diminished. M05, for example, concluded that one component of the binary was a massive star that underwent a thermonuclear event in 2002.

Our observations and distance/reddening determination, however, indicate that the pre-outburst optical light can be attributed *entirely* to the B3 companion, and we know that this companion *is still present*. The actual issue, then, is to explain why the B3 star is now about one magnitude fainter at B than it was before the eruption. We suggest that the explanation is rather prosaic: the B3 companion is close enough to the outbursting component that it is partially submerged in the dust that is being produced copiously and is relatively slowly flowing away from V838 Mon.[6] (Alternatively, the B3 star could be *behind* the cool supergiant, with its light shining through the dust envelope.)

If this is true, then we do not need to account for any extra light in the system before the 2002 outburst. This appears to rule out the presence of any star as massive as star 9, either near the main sequence or in an evolved, even more luminous state (as was proposed by M05).

The B3 companion would also be expected to be reddened by a larger amount than the cluster, if our scenario is correct. However, it is difficult to isolate the color of the B3 star at the present time, because V838 Mon itself still contributes significantly to the system light at the V band and longward.

4.3. Conclusion

Our observations have revealed that V838 Mon belongs to a young cluster. This discovery has, however, only deepened the enigma of V838 Mon and the similar object M31 RV, because we now know that the former arose from a very young population, whereas the latter belongs to a very old population.

Moreover, our discussion suggests that virtually all of the pre-outburst light of the V838 Mon binary was due to the unresolved B3 companion.

What, then, was the nature of the progenitor objects that produced the outbursts of V838 Mon and M31 RV? They apparently can exist at both ends of the range of stellar ages. The luminosity of the progenitor before outburst, at least in the case of V838 Mon, was small compared to that of a B3 dwarf. That would be consistent with the low luminosity of a typical nova-like cataclysmic variable. However, the young age of the V838 Mon cluster would appear to rule out the evolutionary

---

[6]Recent blue spectra of V838 Mon show a strengthening of emission lines due to [Fe II] (Barsukova et al. 2006 as well as our own SMARTS spectra). Barsukova et al. attribute the excitation of these lines to the B3 star, and suggest this indicates that outburst ejecta have reached the vicinity of the B star.

timescale required to produce an accreting white dwarf in a compact binary, a requirement of a nova-like outburst mechanism.

It may be that the stellar-merger scenario advocated in a recent series of papers (e.g., Tylenda & Soker 2006 and references therein; see also Retter et al. 2006, who advocate a planet-star merger) can satisfy these new constraints, provided that collisions between low-mass stars (which exist in all populations) could produce the required high luminosities, and can be shown to occur often enough. At the moment, however, the nature of these extraordinary outbursts remains one of the leading unsolved problems in stellar astrophysics.

We thank the excellent SMARTS 1.3- and 1.5-m service observers for obtaining the data: Claudio Aguilera, Juan Espinoza, David Gonzalez, Sergio Gonzalez, and Alberto Pasten. Fred Walter, Rebecca Winnick, and Jenica Nelan have carried out the telescope scheduling, and data distribution is done by Suzanne Tourtellotte. M. A. would like to thank The Scientific and Technological Research Council of Turkey (TUBITAK) and her advisor Prof. Cafer İbanoğlu, as well as H. E. B. and STScI for their support during her doctoral studies. STScI's participation in the SMARTS consortium is supported by the STScI Director's Discretionary Research Fund. We thank numerous colleagues for discussions of V838 Mon, including especially Lisa Crause, Romano Corradi, Arne Henden, Stefan Kimeswenger, Zolt Levay, Ulisse Munari, Nino Panagia, William Sparks, Sumner Starrfield, Ben Sugerman, Mark Wagner, John Wisniewski, and all of the participants at the La Palma conference on "The Nature of V838 Mon and its Light Echo."

This research has made use of the WEBDA open-cluster database, operated at the Institute for Astronomy of the University of Vienna.

H. E. B. dedicates this paper to the memory of his friend Charles L. Perry.

REFERENCES

Bacher, A., Kimeswenger, S., & Teutsch, P. 2005, MNRAS, 362, 542

Barsukova, E., Goranskij, V., Abolmasov, P., & Fabrika, S. 2006, The Astronomer's Telegram, 803, 1

Bond, H. E. et al. 2003, Nature, 422, 405

Bond, H. E. et al. 2006, in The Nature of V838 Mon and its Light Echo, ed. R. L. M. Corradi & U. Munari (San Francisco: ASP), in press

Bond, H. E., & Siegel, M. H. 2006, AJ, 131, 984

Boschi, F., & Munari U. 2004, A&A, 418, 869

Brown, N. J. 2002, IAU Circ., 7785

Bryan, J., & Royer, R. E. 1992, PASP, 104, 179

Claussen, M., Healy, K., Starrfield, S., & Bond, H. E. 2005, IAU Circ., 8602

Corradi, R. L. M., & Munari, U., eds., 2006, The Nature of V838 Mon and its Light Echo (San Francisco: ASP), in press

Cramer, N. 1997, ESA SP-402: Hipparcos - Venice '97, 311

Crause, L. A., Lawson, W. A., Menzies, J. W., & Marang, F. 2005, MNRAS, 358, 1352

DePoy, D. L., et al. 2003, Proc. SPIE, 4841, 827

Evans, A., Geballe, T. R., Rushton, M. T., Smalley, B., van Loon, J. T., Eyres, S. P. S., & Tyne, V. H. 2003, MNRAS, 343, 1054

Goranskij, V. P., Shugarov, S. Y., Barsukova, E. A., & Kroll, P. 2004, Information Bulletin on Variable Stars, 5511, 1

Henden, A., Munari, U., & Schwartz, M. 2002, IAU Circ., 7859

Johnson, H. L., & Morgan, W. W. 1953, ApJ, 117, 313

Kimeswenger, S., & Eyres, S. P. S. 2006, Information Bulletin on Variable Stars, 5708, 1

Landolt, A. U. 1992, AJ, 104, 340

Lesh, J. R. 1968, ApJS, 17, 371

Martini, P., Wagner, R. M., Tomaney, A., Rich, R. M., della Valle, M., & Hauschildt, P. H. 1999, AJ, 118, 1034

Moitinho, A., Alves, J., Huélamo, N., & Lada, C. J. 2001, ApJ, 563, L73 (MAHL01)

Munari, U., et al. 2005, A&A, 434, 1107 (M05)

Munari, U., & Desidera, S., 2002, IAU Circ., 8005

Perry, C. L. 1973, in IAU Symp. 50, Spectral Classification and Multicolour Photometry, ed. C. Fehrenbach & B. E. Westerlund (Dordrecht: Reidel), 192

Pietrinferni, A., Cassisi, S., Salaris, M., & Castelli, F. 2006, ApJ, 642, 797

Retter, A., Zhang, B., Siess, L., & Levinson, A. 2006, MNRAS, 370, 1573

Rich, R. M., Mould, J., Picard, A., Frogel, J. A., & Davies, R. 1989, ApJ, 341, L51

Schmidt-Kaler, T. 1982, Landolt-Börnstein, Group VI, Vol. 2b, Stars and Star Clusters (Berlin: Springer), 15

Snow, T. P., Zukowski, D., & Massey, P. 2002, ApJ, 578, 877

Sparks, W. B. 2006, in The Nature of V838 Mon and its Light Echo, ed. R. L. M. Corradi & U. Munari (San Francisco: ASP), in press

Stetson, P. B. 1987, PASP, 99, 191

Tylenda, R. 2005, A&A, 436, 1009

Tylenda, R., Crause, L. A., Górny, S. K., & Schmidt, M. R. 2005, A&A, 439, 651

Tylenda, R., & Soker, N. 2006, A&A, 451, 223

Tylenda, R., Soker, N., & Szczerba, R. 2005, A&A, 441, 1099

Wagner, R. M., & Starrfield, S. G. 2002, IAU Circ., 7992

Wisniewski, J. P., Bjorkman, K. S., & Magalhães, A. M. 2003, ApJ, 598, L43 (WBM2003)

Zacharias, N., Monet, D. G., Levine, S. E., Urban, S. E., Gaume, R., & Wycoff, G. L. 2004, BAAS, 205, 48.15

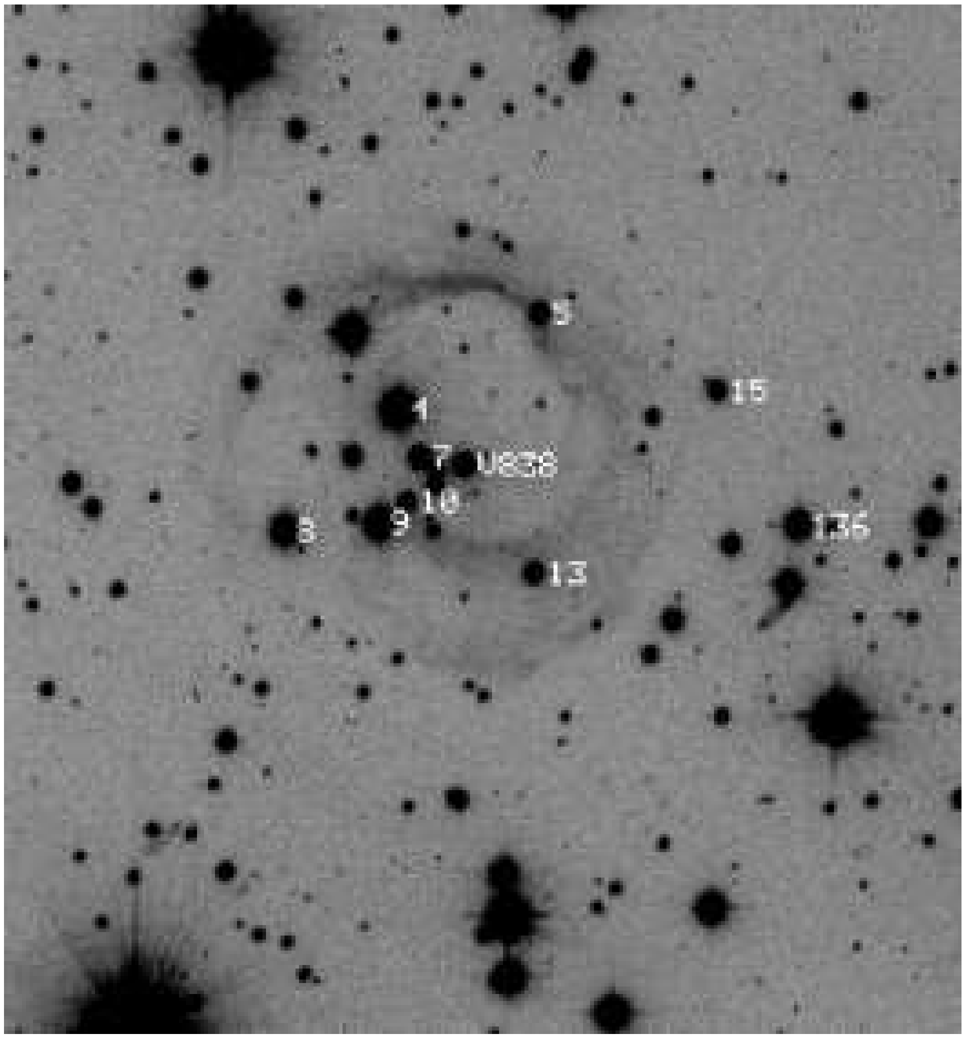

Fig. 1.— Finding chart for stars in the vicinity of V838 Mon, prepared from *B*-band exposures totalling 2000 s obtained with the SMARTS 1.3-m telescope on 2003 December 4. The image is 3′.6 wide and has north at the top and east on the left. The stars numbered 7, 8, and 9 are the newly discovered B-type stars discussed in this paper. The other numbered stars have proven to be unrelated foreground stars, based on our spectroscopic observations with the SMARTS 1.5-m telescope.

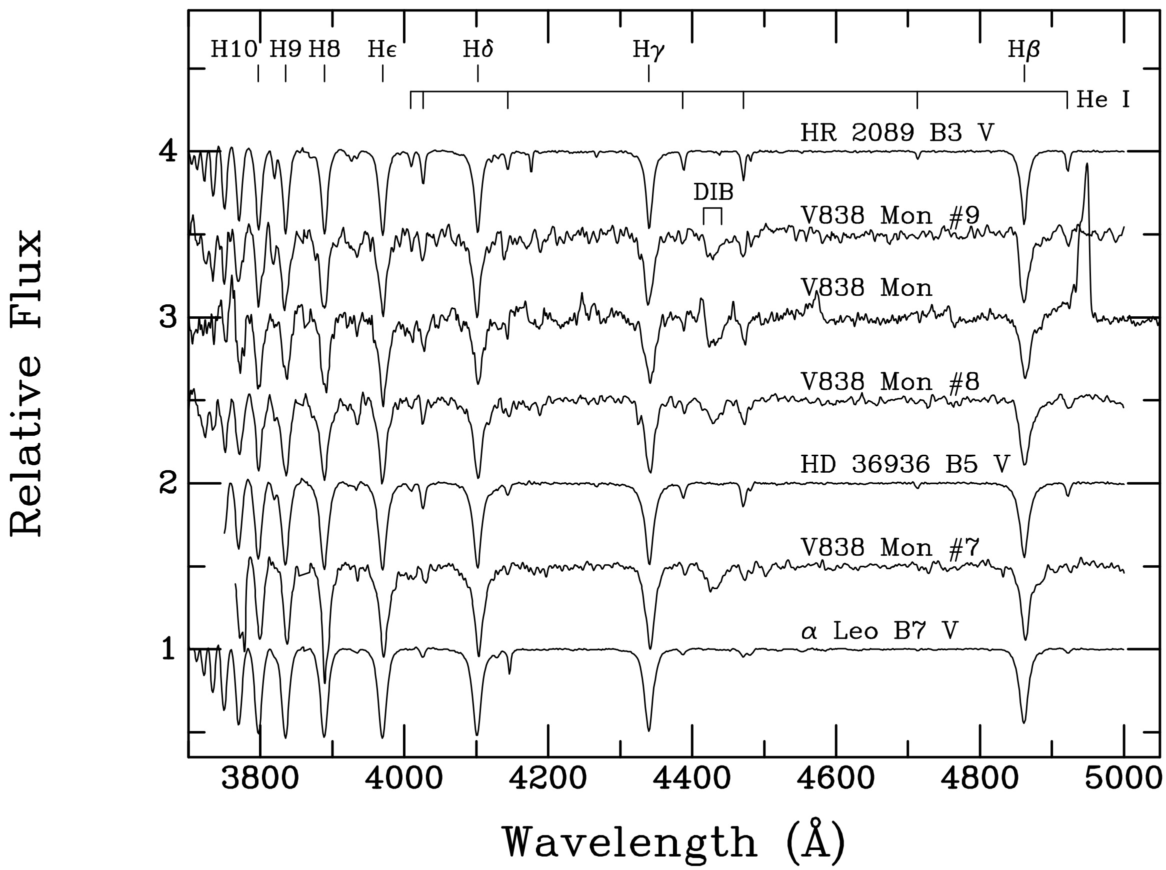

Fig. 2.— SMARTS 1.5-m spectra of three B-type stars belonging to the young cluster in the vicinity of V838 Mon, along with spectra of three classification standards and V838 Mon itself (during early 2003). All spectra have been normalized to a continuum level of 1.0, the tick marks on the y axis are separated by 0.5 continuum flux units, and the spectra have been offset by constant successive amounts. A three-point boxcar smoothing has been applied to the four faint stars. Stars 9, 8, and 7 are classified B3 V, B4 V, and B6 V, respectively, by direct comparison with the classification standards, as described in the text. We also classify the unresolved companion of V838 Mon itself as B3 V. Note the strong diffuse interstellar band (DIB) at 4428 Å in the four reddened stars belonging to the V838 Mon cluster.

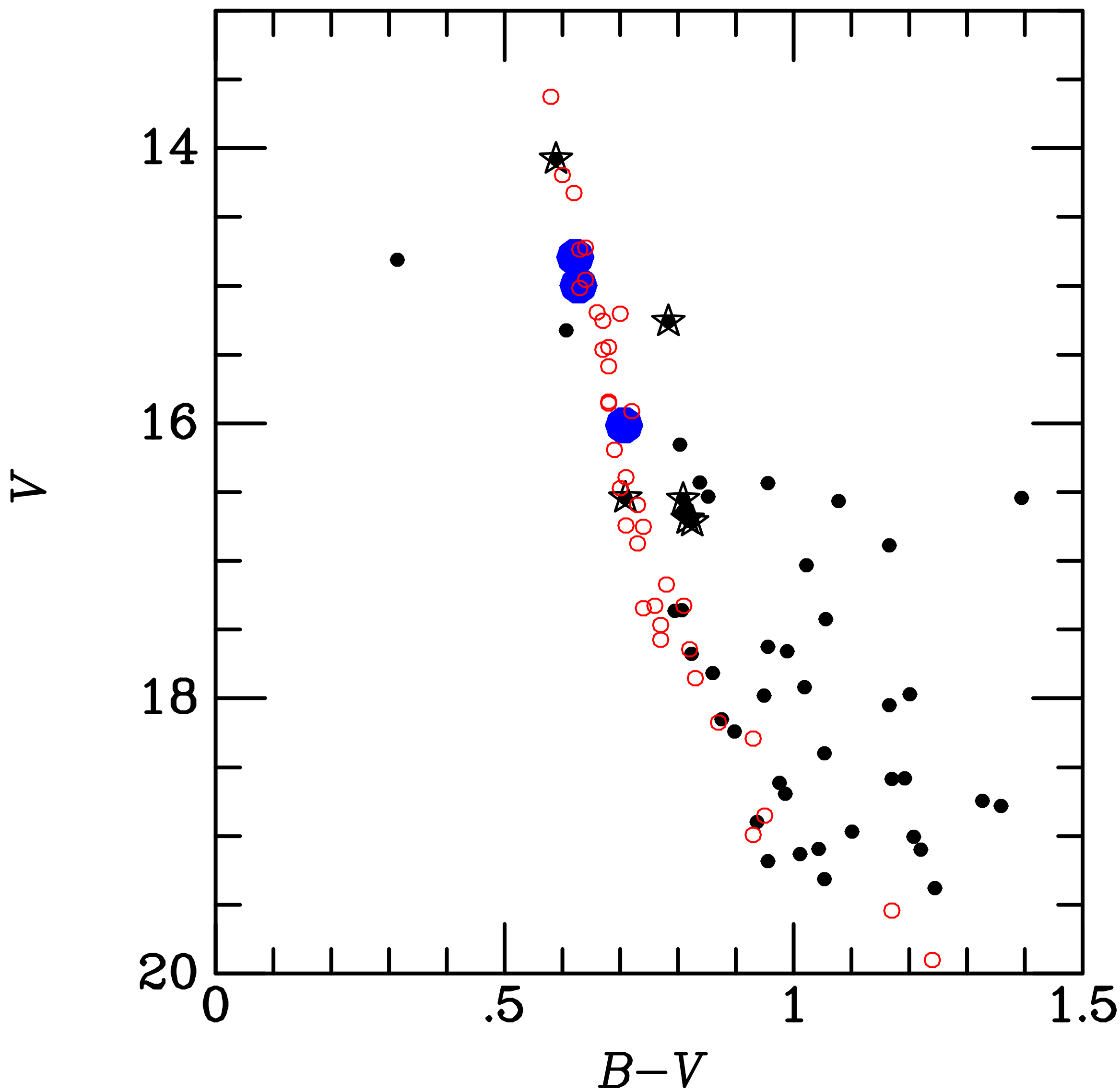

Fig. 3.— Color-magnitude diagram for the three B stars belonging to the V838 Mon cluster (*large blue filled circles*). Also plotted are all stars within a 90″ radius of V838 Mon (*small black filled circles*) for which we do not have spectra, except for six spectroscopically confirmed foreground field stars (*black star symbols*). The *open red circles* plot photometry for the template zero-age main sequence of the open cluster NGC 2362 (Johnson & Morgan 1953; Perry 1973), adjusted to a reddening of $E(B-V) = 0.85$ and a distance of 6.2 kpc; field stars and binaries have been omitted.

Table 1. B-type Stars Near V838 Mon (J2000 Coordinates)

Star No.	WBM2003 No.	M05 No.	α	δ	Sp. Type	V	$B-V$
7	2	197	07:04:05.48	−03:50:49.3	B6 V	16.02	0.71
8	5	159	07:04:07.47	−03:51:06.1	B4 V	15.00	0.63
9	3	110	07:04:06.05	−03:51:03.6	B3 V	14.79	0.62

Table 2. Spectroscopic Parallax Calculations

Star No.	Sp. Type	V	$B-V$	$(B-V)_0$	$E(B-V)$	V_0	M_V	$(m-M)_0$
7	B6 V	16.02	0.71	−0.15	0.86	13.42	−0.9	14.32
8	B4 V	15.00	0.63	−0.19	0.82	12.40	−1.4	13.80
9	B3 V	14.79	0.62	−0.205	$\underline{0.825}$	12.19	−1.6	$\underline{13.79}$
				Mean:	0.84			14.0